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INCIDENCE, SEVERITY, AND GROWTH LOSSES
ASSOCIATED WITH PONDEROSA PINE DWARF MISTLETOE
ON THE KAIBAB NATIONAL FOREST,
ARIZONA

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INCIDENCE, SEVERITY, AND GROWTH LOSSES ASSOCIATED WITH PONDEROSA PINE DWARF MISTLETOE ON THE KAIBAB NATIONAL FOREST, ARIZONA

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ABSTRACT

Forest stands adjacent to 620 miles of forest road were surveyed on the Kaibab National Forest in 1984 to determine the incidence and severity of dwarf mistletoe infection in the commercial ponderosa pine forest cover type. The survey data provided a basis for estimating the magnitude of growth losses associated with dwarf mistletoe. Thirty-four percent of the surveyed stands were mistletoe infected. Of the infected stands, 59 percent had less than one-third of the trees in the managed age class infected, 26 percent of the infected stands had one-third to two-thirds of the trees infected, and 15 percent of the stands had more than two-thirds of the trees in the managed age class infected. Forest-wide, 9,925 acres were surveyed; survey miles and acres were distributed proportionally across all stand size and visual quality classes. Chi-square analyses indicated that there were no significant relationships between stand size classes, visual quality classes, and dwarf mistletoe incidence and severity (P=0.05) in the District-by-District analyses. In the Forest-wide analysis, poletimber and sawtimber stand size classes were significantly correlated with dwarf mistletoe incidence and severity. Mistletoe incidence in poletimber stands was less than would be predicted from the Chi-square distribution; in sawtimber stands, incidence was greater than would be predicted from the same distribution.

A previous Region-wide dwarf mistletoe survey, conducted between 1954-57 (Andrews and Daniels 1960), indicated that 30 percent of the ponderosa pine stands on the Kaibab National Forest were infected with dwarf mistletoe. Results from the 1984 survey indicate that mistletoe incidence has increased 4 percent in the last 25 to 30 years on the Forest.

Total growth losses were estimated using incidence and severity data from the 1984 survey and RMYLD2 growth and yield simulations. When timber management, silviculture, and dwarf mistletoe control were simultaneously optimized in the simulations, the most conservative estimate of annual loss in sawtimber was 8.0 MMBF per year. The corresponding annual loss estimate in pulpwood yield was 2.1 MMCF per year. Small changes in data input into RMYLD2 reflecting changes in timber management emphasis (i.e., focus on nontimber resource objectives), silvicultural prescriptions, and dwarf mistletoe control cutting methods produced large increases in annual loss estimates. We estimate the annual losses in sawtimber and pulpwood growth and yield to be 20 to 30 MMBF and 6 to 8 MMCF, respectively.

INTRODUCTION

Rocky Mountain ponderosa pine (Pinus ponderosa var. scopulorum Engelm.) grows on an estimated 11 million acres in the Southwestern United States. In Arizona and New Mexico, 2.5 million acres are regarded as being commercially productive ($\geq$20 ft^3 per acre per year). On the Kaibab National Forest, 84 percent of the acres of commercial timberland are in the ponderosa pine forest cover type, accounting for an equivalent proportion of the annual harvest volume for this Forest.

Region-wide, over one-third (36%) of the commercial ponderosa pine resource is dwarf mistletoe infected (Arceuthobium vaginatum subsp. cryptopodum (Engelm.) Hawks. and Wiens); by forest, estimates of infection levels range from 15 percent to nearly 65 percent (Andrews and Daniels 1960). Volume losses associated with ponderosa pine dwarf mistletoe are primarily growth losses. By comparison, losses caused by other important disease pests of ponderosa pine, most notably the root rot pathogens Armillaria mellea and Heterobasidion annosum, are related to tree mortality.

The apparent increase in incidence and severity of dwarf mistletoe in southwestern ponderosa pine has been of particular concern to forest pathologists. Observations suggest that stands with histories of repeated selective harvest exhibit the greatest increase in dwarf mistletoe infection severity; data to confirm or disprove this contention have been lacking. The objectives of this evaluation were to: (1) Compare present dwarf mistletoe incidence in the ponderosa pine forest cover type with that found in the preceding (1954-57) survey on the Kaibab National Forest, (2) determine if changes in dwarf mistletoe incidence and severity are related to stand size class or visual quality classifications, and (3) estimate annual growth losses associated with ponderosa pine dwarf mistletoe by Ranger District and Forest-wide.

METHODS

Roadside Survey

This evaluation used the survey methods of Andrews and Daniels (1960), Merrill et al. (1985), and Johnson et al. (1984). Roadside survey-sampling methods were deemed appropriate to this problem analysis since the spread of dwarf mistletoe is not correlated with the presence or impact of forest roading.

The survey determined dwarf mistletoe incidence and severity by combinations of forest cover type, stand size class, and visual quality class. All passable National Forest System roads on each Ranger District were surveyed. Mistletoe data were collected only from acres of pondorosa pine classified as tentatively suitable in the land management planning process. Forest cover type and stand size class of stands adjacent to roads were determined from land management

planning forest cover type maps. The original 16 stand condition classes (FSH 2409.26d, dated November 1975) were condensed for simplification to form 5 broader stand size classes:

Seedlings and saplings (SS); combining 01, 14, and 15
(>4 inches tall; <5.0 inches d.b.h.)

Poletimber (PT); combining 02, 04, 06, 08, 10, and 12
(5.0 to 8.9 inches d.b.h.)

Sawtimber (ST); combining 03, 05, 07, 09, and 13
(9.0 inches and larger)

Overmature timber (OT); 11
(old growth)

Nonstocked (NS); 16

Sensitivity levels and visual quality objectives (FSH 2383.1; Agriculture Handbook No. 462; FSH 2383.16) were combined to reduce the number of visual quality classes, since management practices do not change significantly between some levels. The seven combined classes were:

1. Foreground retention (FR)
2. Other retention (OR)
3. Foreground partial retention (FPR)
4. Level 3 partial retention (3PR)
5. Other partial retention (OPR)
6. Level 3 modification (3M)
7. Other modification (OM)

Visual resource inventory maps (scale 2.64 or 2.0 inches=1 mile) were used to indicate current boundaries of visual quality classes. Changes in forest cover type, stand size class, and visual quality class were clearly marked on survey maps and those maps are archived as a permanent record of the survey.

Two-person crews drove selected roads at speeds not exceeding 10 miles per hour and observed a strip 2 chains wide, measured from the edge of the right-of-way, parallel to the right side of the road. Changes in forest cover type, stand size class, visual quality class, and dwarf

mistletoe severity were visually estimated and recorded to the nearest 0.10 mile using the survey vehicles' odometer. Dwarf mistletoe (DM) infection severity was measured in stands as follows:

DM0=No visible infestation in stands.

DM1=Less than one-third of the trees in the managed age class infected.

DM2=One-third to two-thirds of the trees in the managed age class infected.

DM3=More than two-thirds of the trees in the managed age class infected.

At the beginning of the survey, transects 1 chain wide by 2 chains long, perpendicular to the road axis, were established every mile in which infected and uninfected trees in the managed age class were tallied to correct ocular estimates of infection severity. The number of transects gradually decreased as survey crews developed expertise in estimating infection severity.

Survey results were expressed as the ratio of miles traveled adjacent to infected stands to the total miles traveled Forest-wide, by District, stand size class, visual quality class, and dwarf mistletoe infection severity level. A record of the roads surveyed and direction traveled for each road can be found in Figures 6-10 of the Appendix.

Growth Loss Estimations. If all stands on the Forest were mistletoe free, that would represent full volume productivity or potential. It is not now, nor will it ever be, feasible to reach the mistletoe-free state. It is feasible, however, to reduce mistletoe infection severity in stands so that impact on full volume productivity is negligible. The comparison of full productive potential to existing conditions is useful for assessing the magnitude of the problem. In generating sawtimber and pulpwood volume loss estimates, stands representative of the four forested stand size classes (i.e., seedlings and saplings, poletimber, sawtimber, and overmature timber) were projected to rotation age (120 years) using RMYLD2 (Edminster 1978) at the midpoint of each of the four infection severity levels.

Each stand size class was assigned a nominal age:

Seedlings and saplings	=20 years
Poletimber	=50 years
Sawtimber	=100 years
Overmature timber	=200 years

Site index values of 60, 70, and 80 feet (100-year index age) were used in the growth and yield simulations to reflect the range of growing conditions extant on the Forest. Growing stock levels (GSL's) were adjusted whenever possible to reflect site productivity, optimize volume production and product size, and achieve effective dwarf mistletoe control. Differences in yield for stands managed to rotation at each infection severity level represented the impact on volume production attributable to dwarf mistletoe. RMYLD2 output was expressed in yields per acre; losses were assessed by subtracting infected from healthy stand yields. Losses are reported for each District surveyed by stand size class. Acres of tentatively suitable forest land by forest cover type and stand size class were obtained for the Forest from the 1979 Regional assessment and were also extrapolated from the survey. From the 1979 assessment, the total acres of commercial ponderosa pine = 500,388 acres.

Commercial acres by stand size class (percentages based on survey extrapolations):

Seedlings and saplings	= 75,058	acres (15%)
Poletimber	= 100,078	acres (20%)
Sawtimber	= 235,182	acres (47%)
Overmature timber	= 90,070	acres (18%)
Nonstocked	= 0	acres (0%)

Seedling, sapling, and poletimber stands were managed to a 120-year rotation age beginning at 20 and 50 years, respectively. For sawtimber and overmature timber stands, future growth losses to dwarf mistletoe were considered minor; since stand regeneration was imminent for these stands, the understory component was managed to rotation on RMYLD2. For sawtimber stands, the seedlings and saplings stand size class was simulated; for overmature timber stands, the poletimber stand size class was simulated. The underlying assumption used in sawtimber and overmature timber simulations was equivalent infection

levels in the overstory and understory components. Optimum silvicultural prescriptions by site index, stand size class, and dwarf mistletoe infection severity level are shown on Tables 1 and 2.

For all RMYLD2 simulations, dwarf mistletoe infection severity levels (DM) were set at the midpoint of their range:

DM0 = 0 percent infection = PINF 0 ; DMLEV=3.0

DM1 = 16.5 percent infection = PINF 16.5; DMLEV=3.0

DM2 = 49.5 percent infection = PINF 49.5; DMLEV=3.0

DM3 = 82.5 percent infection = PINF 82.5; DMLEV=6.0

(PINF is the equivalent RMYLD2 input variable)

To arrive at estimates of potential volume production for DM3=82.5 percent infection, DMLEV was set at 6.0 (DMLEV is the input variable in RMYLD2 that indicates the dwarf mistletoe rating (DMR) above which thinnings will not be performed (Edminster 1978; Hawksworth 1977).

RESULTS

Dwarf mistletoe was found in 34 percent of the ponderosa pine stands on the Kaibab National Forest. Of the 620.3 miles surveyed, 214 miles were mistletoe infected. A total of 9,925 acres were surveyed, equal to 2 percent sampling intensity. Dwarf mistletoe incidence and severity were beneath the Regional average. Table 3 shows dwarf mistletoe incidence by stand size class and District. Mistletoe incidence was greatest on the North Kaibab District and least on the Tusayan District (Figure 1). Table 4 shows mistletoe infection severity combining all stands in each District; it is a condensation of Table 3. On the North Kaibab Ranger District, nearly half (46 percent) of the stands are infected (Figure 1), but 59 percent of the infected stands are less than one-third infected. In seedling, sapling, and poletimber stands, the trend is toward reduced mistletoe severity. In sawtimber stands, however, mistletoe incidence and severity have increased appreciably. Only four percent of the stands on the Tusayan District were mistletoe infected, and most of these infected stands were in poletimber and sawtimber. Mistletoe continues to increase on the Williams District; Tables 3 and 4 show the increase in the seedling, sapling, and sawtimber stands.

Table 5 shows dwarf mistletoe incidence by visual quality class, and Table 6 gives incidence by visual quality class and infection severity level. There were no significant relationships between visual quality classification and dwarf mistletoe infection severity.

Chi-square analyses, comparing observed and expected mistletoe infection levels by stand size classes and visual quality classes, revealed only two significant relationships (Table 7). Forest-wide analyses indicated significant (P=0.05) changes in incidence related to stand size class; in poletimber stands, timber management activities have significantly reduced mistletoe, while significantly increasing mistletoe incidence in sawtimber stands (Figure 2). By District, there were no significant relationships between stand size classes, visual quality classes, and mistletoe infection severity (Table 7 and Figure 3).

Estimates of annual growth loss by District are summarized in Table 8. These estimates are not based on simulating current management conditions, but are an expression of growth losses to dwarf mistletoe under the best circumstances, when silviculture and dwarf mistletoe control are optimized coincidentally and all infected stands are entered immediately. A sawtimber-loss estimate of 8.0 MMBF per year, Forest-wide, is the most conservative estimate when mistletoe incidence is 34 percent (Figure 4). Since all stands cannot be entered immediately, current sawtimber losses on the Kaibab National Forest exceed 20 MMBF per year and may run as high as 30 MMBF per year. This is confirmed in yield projections that allow delayed entry. A comparable inflation applies to cubic foot volume losses as well (i.e., 6-8 MMCF per year).

Based on the results of their 1954-57 mistletoe survey, Andrews and Daniels (1960) concluded that 30 percent of the commercial ponderosa pine stands on the Kaibab National Forest were infected with dwarf mistletoe. This estimate was based on a plot survey; 249 plots were taken on the Forest. We analyzed the unpublished data from their roadside survey, from that same period, and found that it corroborated the results of their plot survey for the Districts they surveyed. We feel that the older plot and roadside survey information is accurate and it serves as an appropriate yardstick upon which to evaluate the results of this current survey. Dwarf mistletoe incidence has increased from 30 to 34 percent in 25 to 30 years on the Kaibab National Forest (Figure 5).

DISCUSSION

The results of the 1984 dwarf mistletoe survey indicate a trend of increasing incidence and severity. We attribute some of the increased incidence to 25 or more years of selective harvesting. The propensity to prescribe preparatory cuts in succession, where seed cuts or final removals were needed, has perpetuated unevenaged stand conditions and increased the rate of spread of the disease. Past management emphasis was inappropriate to reducing dwarf mistletoe; cutting out the volume was most important. Trees that were selected for harvest were scattered throughout stands and usually were the largest and healthiest individuals. What remained after each selective harvest was a higher proportion of inferior quality, mistletoe-infected trees.

Openings created by selective removals were naturally regenerated, stands were unevenaged and multistoried, and dwarf mistletoe spread quickly into the new understory. We surmise that a portion of the increase in dwarf mistletoe incidence is real increase (i.e., new infection of previously healthy trees), but perhaps an equally important portion is that which has resulted from increasing the diseased proportion in stands by selective harvesting.

The increased incidence and severity of dwarf mistletoe infection on the Kaibab National Forest is significant, and management objectives should reflect a concerted effort to reduce dwarf mistletoe effects on growth and yield. Unchecked, the mistletoe problem will worsen and the magnitude of associated growth losses will increase. The trend can be reversed through improvement in silvicutural treatments.

In general, dwarf mistletoe spreads most slowly in single-story, even-aged stands of any age. Small departures from even-aged management result in radical increases in dwarf mistletoe incidence and severity. In the RMYLD2 growth and yield simulations that were used to estimate volume losses, stocking was drastically reduced in infected stands at the earliest possible time to reduce stand DMR's. Without this early reduction in stocking, stands were destroyed by dwarf mistletoe before rotation age. Volume loss estimates assume that thinning entries or regeneration cuts were made in every stand at the most opportune time. Departures from this management strategy resulted in reductions in timber yield much worse than reported here.

In addition to documenting mistletoe incidence, severity, and associated growth losses, it is intended that these survey results will draw to a focus the scope and principal causes of the problem, so that corrective timber management decisions can be made to reverse the trend of increasing mistletoe severity on the Forest.

The principal causes as we see them are:

1. A repeated history of selective harvesting in dwarf mistletoe-infected stands.

2. Silvicultural prescriptions that perpetuated unevenaged stand conditions. The ponderosa pine cover type consisted of a mosaic of uneven-aged clumps of trees. Following selective overstory removals, portions of every stand were naturally regenerated. Seed cuts were rare and total overstory removals almost nonexistent.

3. Lack of priority given to treating mistletoe-infected stands. Entire timber sale areas were selectively harvested to produce a targeted volume. Little thought was given to delineating specific cutting units for the primary purpose of controlling dwarf mistletoe. By giving mistletoe-infected stands high treatment priority in timber sales, two major works could be accomplished: (a) The targeted volume could be realized from fewer acres and (b) greater volume would be produced in properly treated stands that could be harvested in subsequent entries.

4. Ineffective cutting methods when dwarf mistletoe was the intended object of silvicultural prescriptions. Visibly infected overstory trees were removed, but trees with little evidence of witches' broom formation were retained in the overstory. Seeds discharged from mistletoe plants in the residual overstory trees provided the inoculum source for further overstory and understory infections. In most cases, a seed cut and overstory removal, followed by judicious thinning in the understory, would have reduced the presence of the dwarf mistletoe in stands to acceptable levels.

5. Lack of a consistent approach or policy for controlling dwarf mistletoe in stands of all sizes. Table 3 shows the breakdown of dwarf mistletoe infection severity by size class; Table 7 indicates those increments and decrements that are significant. On Table 3, mistletoe incidence in seedling, sapling, and poletimber stands is less than Forest-wide mistletoe incidence. Incidence in sawtimber stands is much greater than the Forest-wide estimate. Statistical analysis indicates that the increase in mistletoe incidence in sawtimber stands is significantly greater than could be predicted. Selective harvest methods have increased dwarf mistletoe incidence in sawtimber stands. Since one-half of the commercial land base for the Kaibab National Forest is in sawtimber stands (see page 6), a considerable proportion of the future volume production is expected to be generated by these stands. That volume can be easily realized from both infected and uninfected stands with implementation of the proper cutting methods. Additionally, mistletoe incidence is most easily reduced when stands are regenerated. Since the Kaibab National Forest has most of its mistletoe infection in sawtimber stands, there is an excellent opportunity to reduce Forest-wide incidence and severity within a shortened time frame.

The growth losses estimated and presented reflect the level of damage and loss associated with mistletoe at the present level of incidence. Losses will decrease with reductions in the number and distribution of infected trees in stands. The solution to the problem lies in improving stand management by treating infected stands first, thereby reducing mistletoe incidence in stands, one stand at a time. It is important that mistletoe incidence routinely becomes a major decision variable when stand treatments are prioritized and cutting units are selected in timber sales. Prescriptions need to reflect a major emphasis of reducing stand DMR, while trying to reflect stocking, spacing, and tree diameter objectives. Dwarf mistletoe is endemic in southwestern ponderosa pine forests, but its impact can be reduced with proper management so that the effects are negligible.

Chapter 70 in the Cutting Methods Handbook (FSH 2409.26a, dated December 1984) was prepared as a field aid for dealing with mistletoe-infected stands. Information is given on rating infected trees and whole stands, and methods are presented which aid in the complex process of determining which cutting units should be entered and which can be deferred. Sections on regeneration and intermediate cutting methods are also included. Much of the time these materials will provide the necessary guidance. If additional technical assistance is

needed, pathologists in the Regional Office are available to help evaluate mistletoe problems and assist in formulating prescriptions to control dwarf mistletoe in specific cutting units.

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APPENDIX

TABLE 1.--Optimum prescriptions for RMYLD2 growth and yield simulations for the Kaibab National Forest seedlings and saplings (SS)

SSC[1]	AGE (yrs)	SITE INDEX	DMR[4] START (0-6)	PINF[4] START %	DMR[5] FINAL (0-6)	THIN1[4] (GSL)	DSTY1[4] (GSL)	DSTY2[4] (GSL)	DBH[5] CUT (in)	DBH[5] RESID. (in)	VOLUME OUT[5] MBF/AC	VOLUME OUT[5] MCF/AC	CULM. MAI[3] AGE (yrs)	CULM. MAI[3] ft^3
SS	20	60	0	0	0	60	60	60	19.1	16.6	14.9	3.5	100	27
			0.2	16.5	.0+	40	40	40	21.7	19.7	12.2	2.7	100	21
			0.7	49.5	.0+	20	40	40	21.9	19.7	11.6	2.5	120	20
(Regenerate)[2]			2.6	82.5	6.0	20	20	20	21.4	21.3	0.6	0.1	70	8
SS	20	70	0	0	0	60	60	60	20.4	18.0	17.9	4.1	100	32
			0.2	16.5	.0+	40	60	60	20.4	17.8	17.5	4.0	110	31
			0.7	49.7	.0+	40	40	40	22.9	20.7	14.3	3.2	100	25
(Regenerate)[2]			2.6	82.5	5.5	20	20	20	23.5	27.9	4.5	1.0	90	12
SS	20	80	0	0	0	60	70	70	20.5	18.0	23.8	5.6	100	43
			0.2	16.5	.0+	40	60	60	21.4	19.1	21.5	4.8	100	37
			0.7	49.5	.0+	40	50	50	22.6	20.3	19.5	4.3	100	33
(Regenerate)[2]			2.6	82.5	4.8	20	20	20	26.2	31.6	8.9	1.8	100	16

[1]SSC is stand size class.
[2]Unable to reduce dwarf mistletoe to acceptable levels; regenerate the stand.
[3]Culmination of mean annual increment.
[4]Input variables for data entry into RMYLD2; DMR START=DMR(1) stand dwarf mistletoe rating; PINF START=PINF(1) percent mistletoe infected; THIN1=growing stock level achieved with initial thinning; DSTY1 and 2=growing stock level or density achieved with subsequent entries. (Edminster 1978).
[5]Output from RMYLD2; DMR FINAL=stand dwarf mistletoe rating at rotation; DBH CUT=average diameter of sawtimber cut during the seed cut; DBH RESID.=average residual seed tree diameter; VOLUME OUT=commercial volume produced per acre.

TABLE 2.--Optimum prescriptions for RMYLD2 growth and yield simulations for the Kaibab National Forest poletimber (PT)

SSC[1]	AGE (yrs)	SITE INDEX	DMR[4] START (0-6)	PINF[4] START %	DMR[5] FINAL (0-6)	THIN1[4] (GSL)	DSTY1[4] (GSL)	DSTY2[4] (GSL)	DBH[5] CUT (in)	DBH[5] RESID. (in)	VOLUME OUT[5] MBF/AC	VOLUME OUT[5] MCF/AC	CULM. MAI.[3] AGE (yrs)	CULM. MAI.[3] ft^3
PT	50	60	0	0	0	60	60	60	19.5	16.8	14.2	3.5	130	25
			0.2	16.5	.0+	40	50	50	19.3	16.7	12.1	3.2	110	22
			0.7	49.5	.0+	40	50	50	19.3	16.7	12.1	3.2	110	22
(Regenerate)[2]			2.6	82.5	4.5	20	20	20	22.3	27.6	5.0	1.5	120	12
PT	50	70	0	0	0	60	70	70	20.0	17.5	18.9	4.3	120	31
			0.2	16.5	.0+	40	60	60	19.5	16.9	16.5	4.1	120	29
			0.7	49.5	.0+	40	60	60	19.5	16.9	16.5	4.1	120	29
(Regenerate)[2]			2.6	82.5	3.9	20	20	20	23.5	28.2	7.8	2.1	120	15
PT	50	80	0	0	0	60	70	70	21.6	19.4	24.0	5.4	130	39
			0.2	16.5	.0+	40	60	60	20.5	18.1	19.6	5.1	130	37
			0.7	49.5	.0+	40	60	60	20.5	18.1	19.6	5.1	130	37
(Regenerate)[2]			2.6	82.5	2.8	20	30	30	23.1	27.0	12.1	3.4	130	25

[1]SSC is stand size class.
[2]Unable to reduce dwarf mistletoe to acceptable levels; regenerate the stand.
[3]Culmination of mean annual increment.
[4]Input variables for data entry into RMYLD2; DMR START=DMR(1) stand dwarf mistletoe rating; PINF START=PINF(1) percent mistletoe infected; THIN1=growing stock level achieved with initial thinning; DSTY1 and 2=growing stock level or density achieved with subsequent entries. (Edminster, 1978).
[5]Output from RMYLD2; DMR FINAL=stand dwarf mistletoe rating at rotation; DBH CUT=average diameter of sawtimber cut during the seed cut; DBH RESID.=average residual seed tree diameter; VOLUME OUT=commercial volume produced per acre.

TABLE 3.--Dwarf mistletoe infection severity estimates by stand size class for Districts on the Kaibab National Forest

RANGER DISTRICT		STAND SIZE CLASS															
		SEEDLINGS/SAPLINGS				POLETIMBER				SAWTIMBER				OVERMATURE			
		0	1	2	3[1]	0	1	2	3	0	1	2	3	0	1	2	3
WILLIAMS	MI[2]	2.1	0.1	0.3	1.7	32.0	8.8	3.7	4.0	31.3	11.5	5.5	5.5	4.4	1.0	0.3	0.1
	%[3]	50	2	7	41	66	18	8	8	58	21	10	10	76	17	5	2
CHALENDER	MI	3.1	0.6	0.1	0.7	26.5	4.3	1.4	1.1	43.7	11.2	3.5	1.5	4.1	0.7	0.4	0
	%	69	13	2	16	80	13	4	3	73	19	6	3	79	14	8	0
TUSAYAN	MI	23.0	0.2	0	0	34.3	0.9	0.9	0.1	27.7	1.2	0.2	0	5.5	0	0	0
	%	99	1	0	0	95	3	3	0	95	4	1	0	100	0	0	0
NORTH KAIBAB	MI	36.8	12.4	7.0	3.6	4.6	1.5	0.4	0.1	70.9	49.3	17.9	10.7	55.7	21.7	12.7	5.2
	%	62	21	12	6	70	23	6	2	48	33	12	7	59	23	13	6
FOREST TOTALS	MI	65.0	13.3	7.4	6.0	97.4	15.5	6.4	5.3	173.6	73.2	27.1	17.7	69.7	23.4	13.4	5.3
	%	71	15	8	7	78	12	5	4	60	25	9	6	62	21	12	5

[1]Dwarf mistletoe infection severity level.
[2]Miles of road surveyed in stands of a particular size class and infection severity level.
[3]Percentages are computed within the stand size class for a single District, and are rounded up to nearest whole percentage.

TABLE 4.--Comparision of dwarf mistletoe infection severity levels between Districts on the Kaibab National Forest

RANGER DISTRICT		DWARF MISTLETOE INFECTION SEVERITY					
		DM(-)[1]	DM(+)[2]	DM1[5]	DM2[5]	DM3[5]	SUBTOTAL
WILLIAMS	MI[6]	70.4	42.5	21.4	9.8	11.3	112.9[3]
	%[7]	62	38	19	9	10	18[4]
CHALENDER	MI	77.4	25.5	16.8	5.4	3.3	102.9[3]
	%	75	25	17	5	3	17[4]
TUSAYAN	MI	90.5	3.5	2.3	1.1	0	94.0[3]
	%	96	4	3	1	0	15[4]
NORTH KAIBAB	MI	168.0	142.5	84.9	38.0	19.6	310.5[3]
	%	54	46	27	12	7	50[4]
FOREST TOTALS	MI	406.3	214.0	125.4	54.3	34.2	620.3
	%	66	34	20	9	5	100

[1]Miles of ponderosa pine stands surveyed without dwarf mistletoe infection.
[2]Miles of ponderosa pine stands surveyed with dwarf mistletoe infection of severity levels (1, 2, or 3).
[3]Miles surveyed in a District.
[4]Percentage of Forest-wide survey miles.
[5]Dwarf mistletoe infection severity level.
[6]Miles surveyed in stands within a District and infection severity level.
[7]Percentage of total miles surveyed in a District within an infection severity level.

TABLE 5.--Dwarf mistletoe incidence by visual quality class for Districts on the Kaibab National Forest

RANGER DISTRICT	DM	FR[1] (-)[2]	FR[1] (+)[3]	OR[1] (-)	OR[1] (+)	FPR[1] (-)	FPR[1] (+)	3PR[1] (-)	3PR[1] (+)	OPR[1] (-)	OPR[1] (+)	3M[1] (-)	3M[1] (+)	OM[1] (-)	OM[1] (+)	SUBTOTAL (-)	SUBTOTAL (+)
WILLIAMS	MI[4]					10.0	4.7			3.6	2.1	56.8	35.7			70.4	42.5
	%[5]					68	32			63	37	61	39			62	38
CHALENDER	MI					10.7	2.3			0.1	0.1	66.6	23.1			77.4	25.5
	%					82	18			50	50	74	26			75	25
TUSAYAN	MI					1.0	0					89.5	3.5			90.5	3.5
	%					100	0					96	4			96	4
NORTH KAIBAB	MI					17.7	10.0					150.3	132.5			168.0	142.5
	%					64	36					53	47			54	46
FOREST TOTALS	MI					39.4	17.0			3.7	2.2	363.2	194.8			406.3	214.0
	%					70	30			63	37	65	35			66	34

[1]Visual quality classes (see page 4 for an explanation of abbreviations).
[2]Surveyed stands without dwarf mistletoe infection.
[3]Surveyed stands with dwarf mistletoe infection of severity level 1, 2, or 3.
[4]Miles of road surveyed in stands within a District, in a given visual quality class.
[5]Percentage of total miles of road surveyed within a District, in a given visual quality class.

TABLE 6.--Comparison of dwarf mistletoe infection severity estimates by visual quality class for Districts on the Kaibab National Forest

RANGER DISTRICT	DM	FPR[1] 0	FPR[1] 1	FPR[1] 2	FPR[1] 3[2]	OPR[1] 0	OPR[1] 1	OPR[1] 2	OPR[1] 3	3M[1] 0	3M[1] 1	3M[1] 2	3M[1] 3
WILLIAMS	MI[3]	10.0	1.5	1.1	2.1	3.6	1.0	1.1	0	56.8	18.9	7.6	9.2
	%[4]	68	10	8	14	63	18	19	0	61	20	8	10
CHALENDER	MI	10.7	2.1	0.2	0	0.1	0.1	0	0	66.6	14.6	5.2	3.3
	%	82	16	2	0	50	50	0	0	74	16	6	4
TUSAYAN	MI	1.0	0	0	0					89.5	2.3	1.1	0.1
	%	100	0	0	0					96	3	1	0
NORTH KAIBAB	MI	17.7	4.0	4.8	1.2					150.3	80.9	33.2	18.4
	%	64	15	17	4					53	29	12	7
FOREST TOTALS	MI	39.4	7.6	6.1	3.3	3.7	1.1	1.1	0	363.2	116.7	47.1	31.0
	%	70	13	11	6	63	19	19	0	65	21	8	6

[1]Visual quality class (see page 4 for an explanation of abbreviations).
[2]Dwarf mistletoe infection severity level.
[3]Miles of road surveyed in stands within Districts, visual quality classes, and infection severity levels.
[4]Percentage of total miles surveyed within a District and visual quality class.

TABLE 7.--Summary of Chi-square analyses comparing observed and expected mistletoe incidence[1] by stand size classes and visual quality classes (P=0.05)

RANGER DISTRICT			STAND SIZE CLASSES				VISUAL QUALITY CLASSES		
			SS[3]	PT[3]	ST[3]	OT[3]	FPR[4]	OPR[4]	3M[4]
WILLIAMS	(O_i-E_i)	MI[5]	+0.5	-1.9	+2.1	-0.8	-0.9	-0.1	+0.5
		SIG.[2]	NS	NS	NS	NS	NS	NS	NS
CHALENDER		MI	+0.3	-1.5	+1.2	-0.2	-1.0	+0.1	+0.7
		SIG.	NS	NS	NS	NS	NS	NS	NS
TUSAYAN		MI	-0.7	+0.5	+0.2				-0.2
		SIG.	NS	NS	NS				NS
NORTH KAIBAB		MI	-0.8	-0.6	-3.0	+4.7	-3.8		+4.0
		SIG.	NS	NS	NS	NS	NS		NS
FOREST-WIDE		MI	-4.5	-15.2	+18.9	+4.1	-2.2	+0.2	+5.1
		SIG.	NS	S	S	NS	NS	NS	NS

[1]Dwarf mistletoe incidence is presented as miles of stands surveyed with any mistletoe infection, by stand size class, visual quality class, and District.
[2]Denotes significance at P=0.05; NS is not significant, S is significant.
[3]SS=seedling and sapling stands; PT=poletimber stands; ST=sawtimber stands; OT=overmature stands.
[4](See page 4 for an explanation of abbreviations).
[5]Difference between the observed (O_i) number of miles of road surveyed with mistletoe infection and the expected (E_i) number of miles with mistletoe infection as predicted by the Chi-square distribution.

TABLE 8.--Minimum estimate[1] of annual losses in sawtimber and pulpwood production on the Kaibab National Forest

RANGER DISTRICT		SEEDLINGS AND SAPLINGS (SS) MMBF/YR	SEEDLINGS AND SAPLINGS (SS) MMCF/YR	POLETIMBER (PT) MMBF/YR	POLETIMBER (PT) MMCF/YR	SAWTIMBER (ST) MMBF/YR	SAWTIMBER (ST) MMCF/YR	OVERMATURE TIMBER (OT) MMBF/YR	OVERMATURE TIMBER (OT) MMCF/YR	SUBTOTAL MMBF/YR	SUBTOTAL MMCF/YR
WILLIAMS											
	VOL.	0.8	0.4	0.3	0.1	1.0	0.3	0.2	.0+	2.3	0.8
	%[2]	35	50	13	13	43	38	9	0	29	38
CHALENDER											
	VOL.	0.3	0.1	0.2	.0+	0.4	0.1	0.1	.0+	1.0	0.2
	%	30	50	20	0	40	50	10	0	13	10
TUSAYAN											
	VOL.	.0+	.0+	.0+	.0+	.0+	.0+	0	0	.0+	.0+
	%	0	0	0	0	0	0	0	0	0	0
NORTH KAIBAB											
	VOL.	0.7	0.2	0.5	0.1	2.7	0.7	0.8	0.1	4.7	1.1
	%	15	18	11	9	57	64	17	9	59	52
FOREST TOTAL											
	VOL.	1.8	0.7	1.0	0.2	4.1	1.1	1.1	0.1	8.0	2.1
	%	23	33	13	10	51	52	14	5	100	100

[1]Estimates based on RMYLD2 growth and yield projections using incidence and severity data from the survey.
[2]Percentage of District losses in a stand size class.

FIGURE 1. Comparison of DM Incidence between Districts and the trend towards increased infection severity

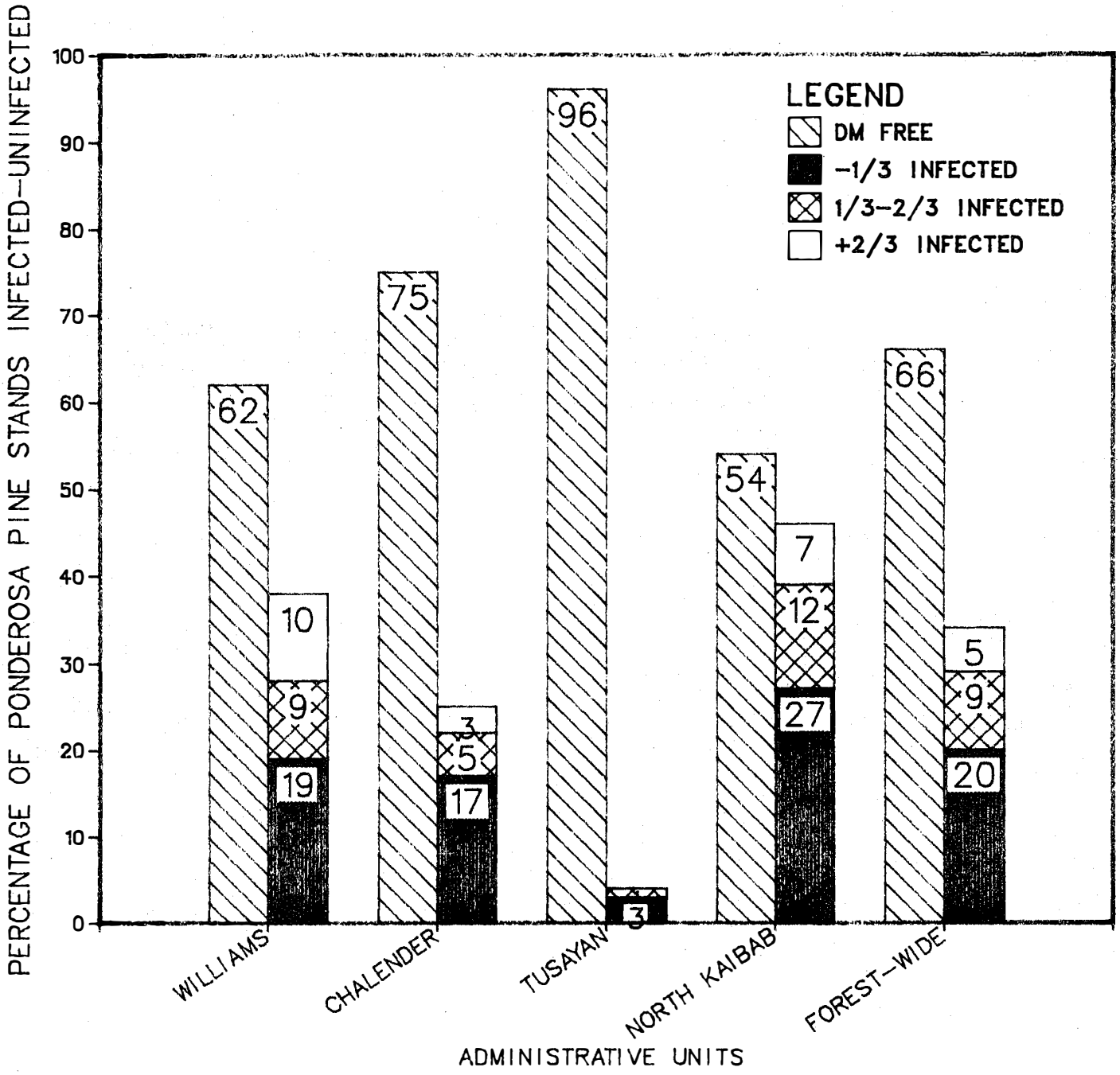


FIGURE 2. Comparison of observed and expected DM incidence by size class for the Kaibab National Forest

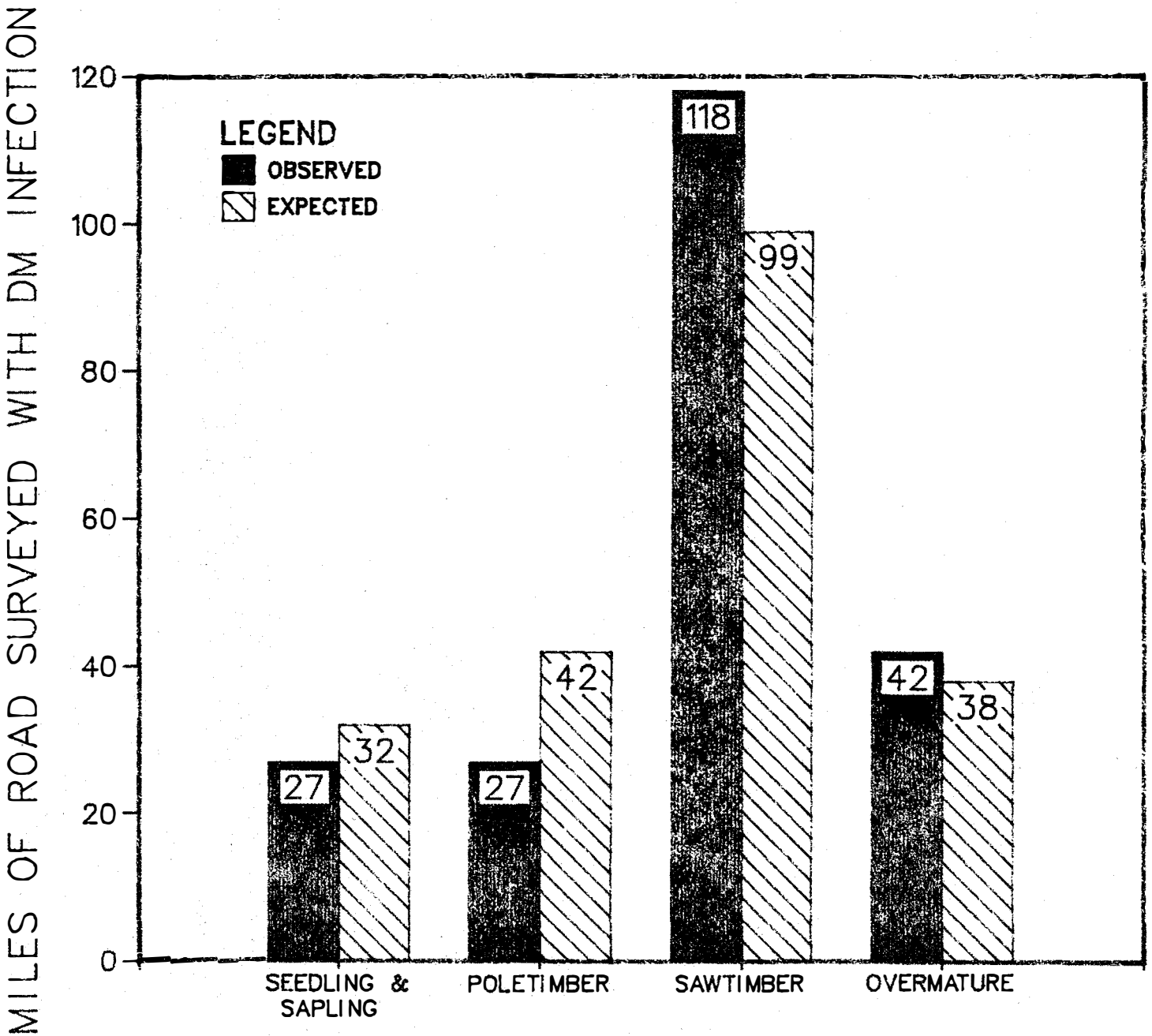


FIGURE 3. Comparison of observed and expected DM incidence by visual quality class for the Kaibab National Forest

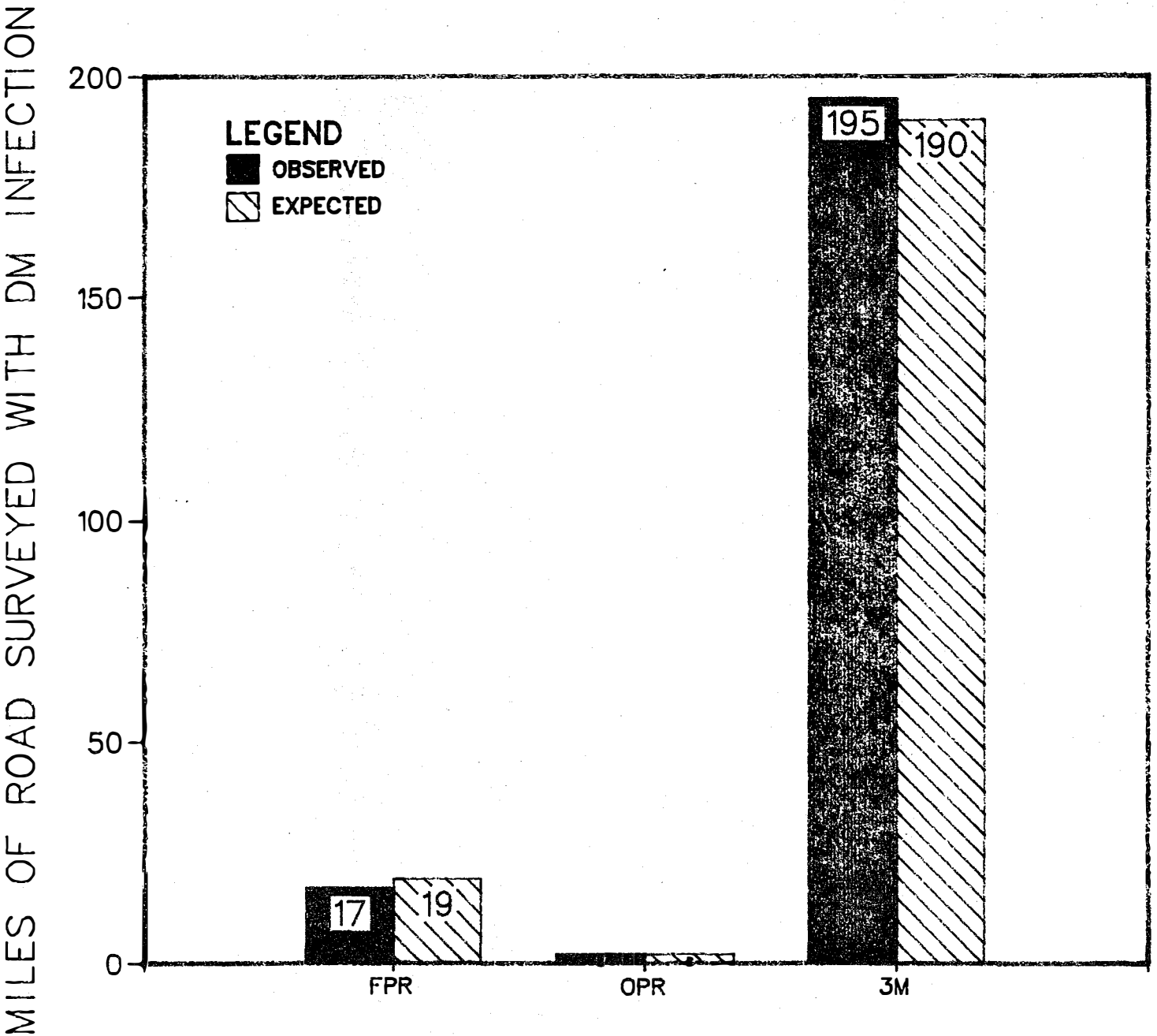


FIGURE 4. Distribution of projected annual volume losses by size class for the Kaibab National Forest

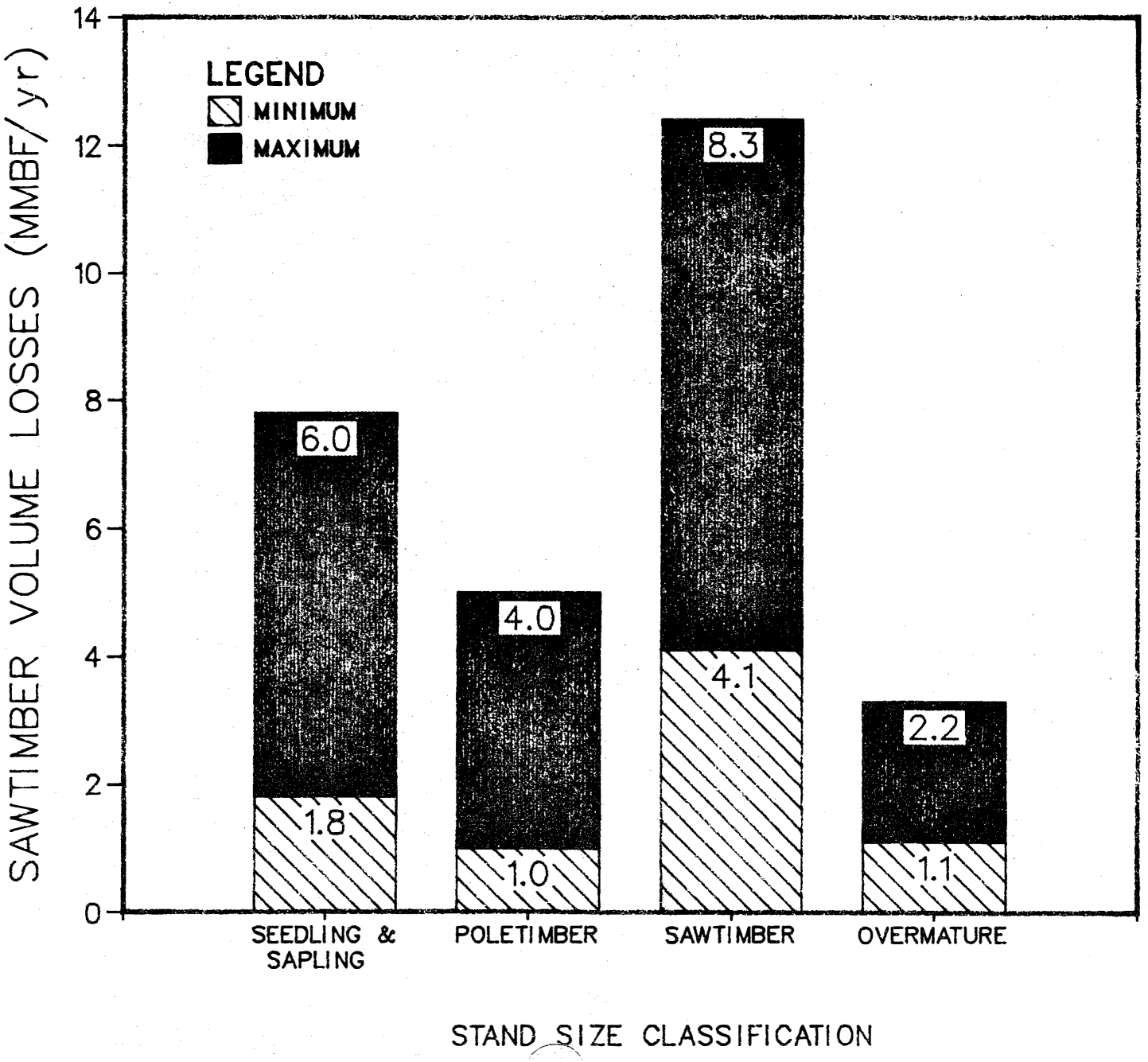
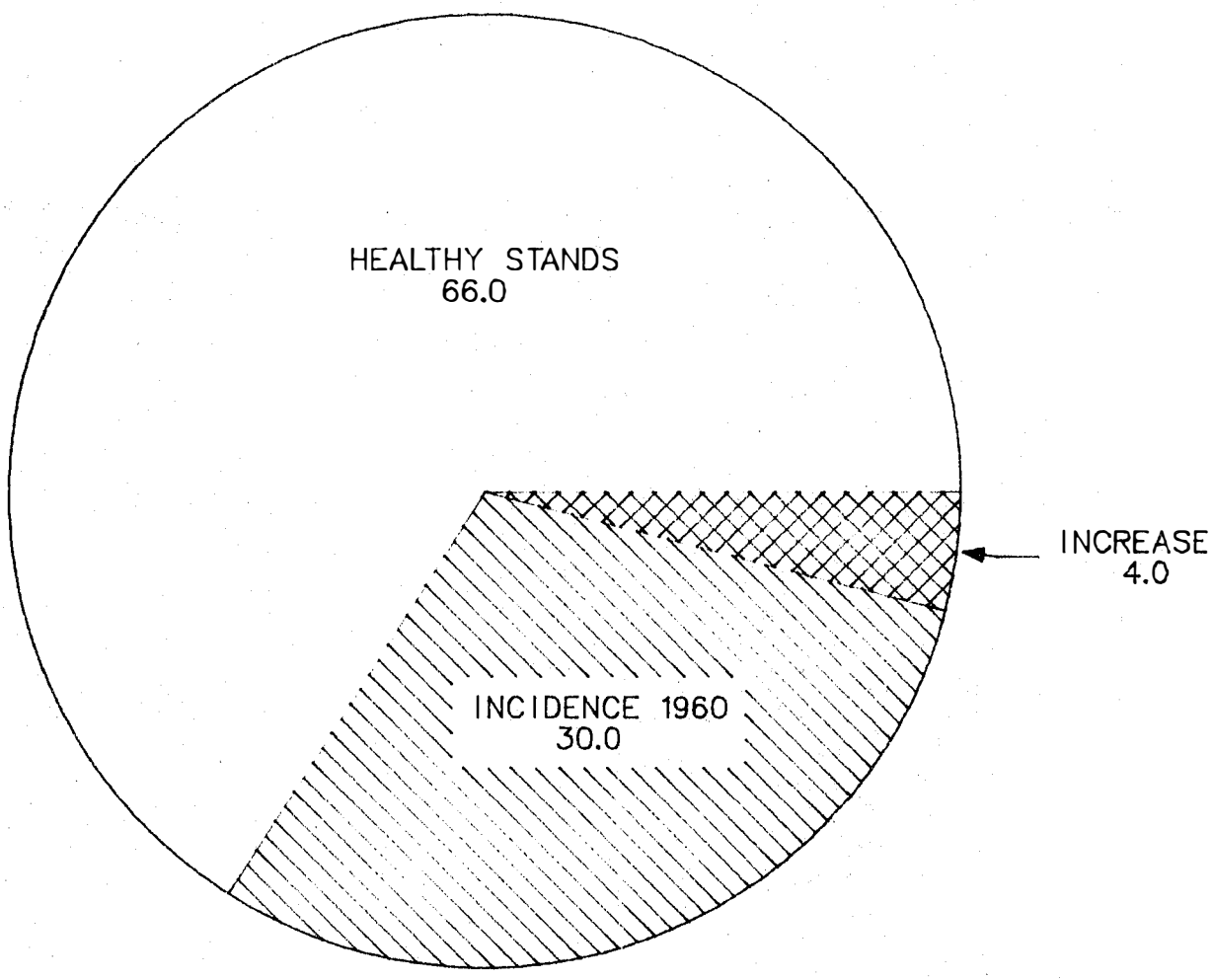


FIGURE 5. Increase in dwarf mistletoe incidence in commercial ponderosa pine stands on the Kaibab National Forest from 1960–1984



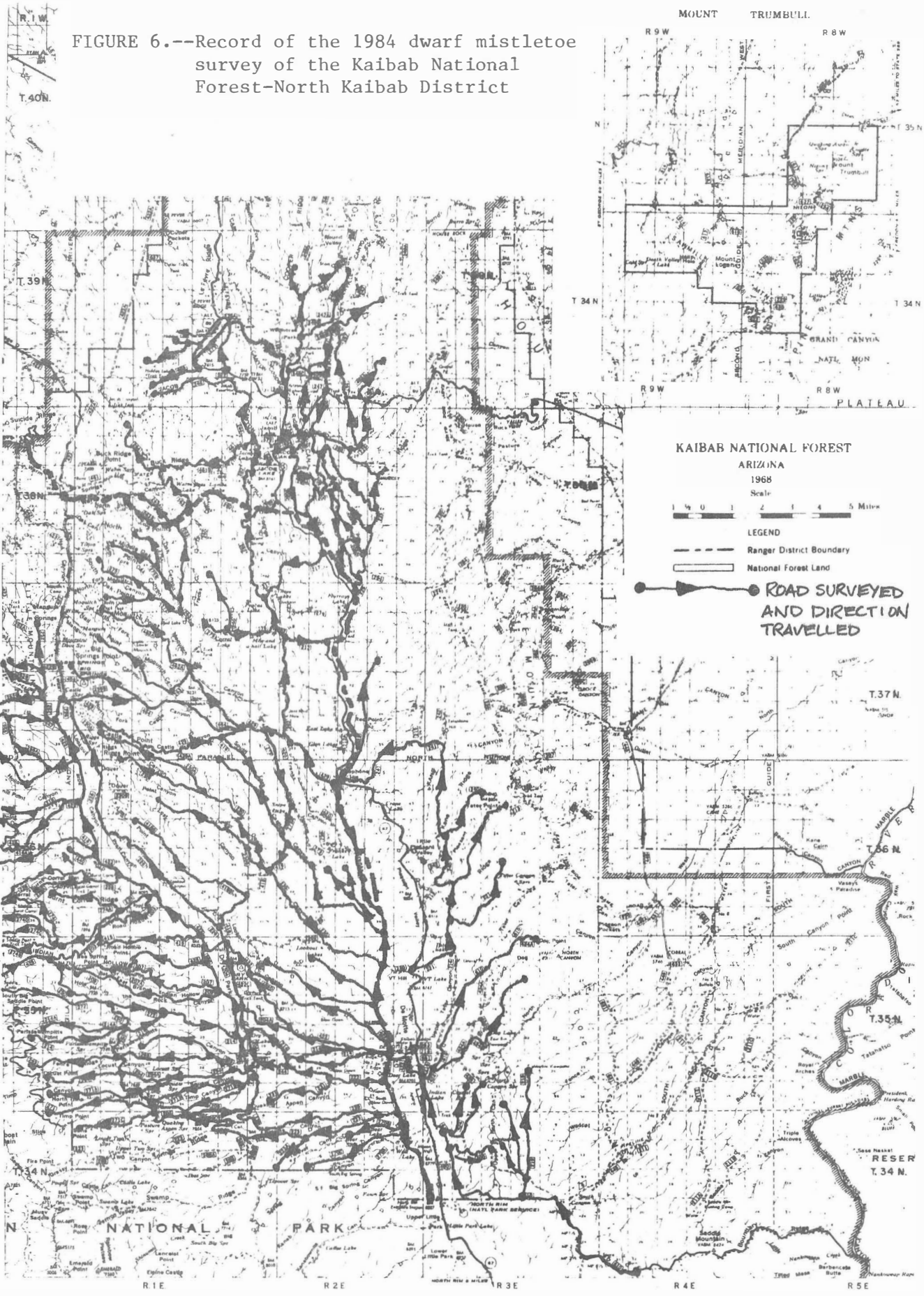


FIGURE 6.--Record of the 1984 dwarf mistletoe survey of the Kaibab National Forest-North Kaibab District

FIGURE 7.--Record of the 1984 dwarf mistletoe survey of the Kaibab National Forest-North Kaibab District

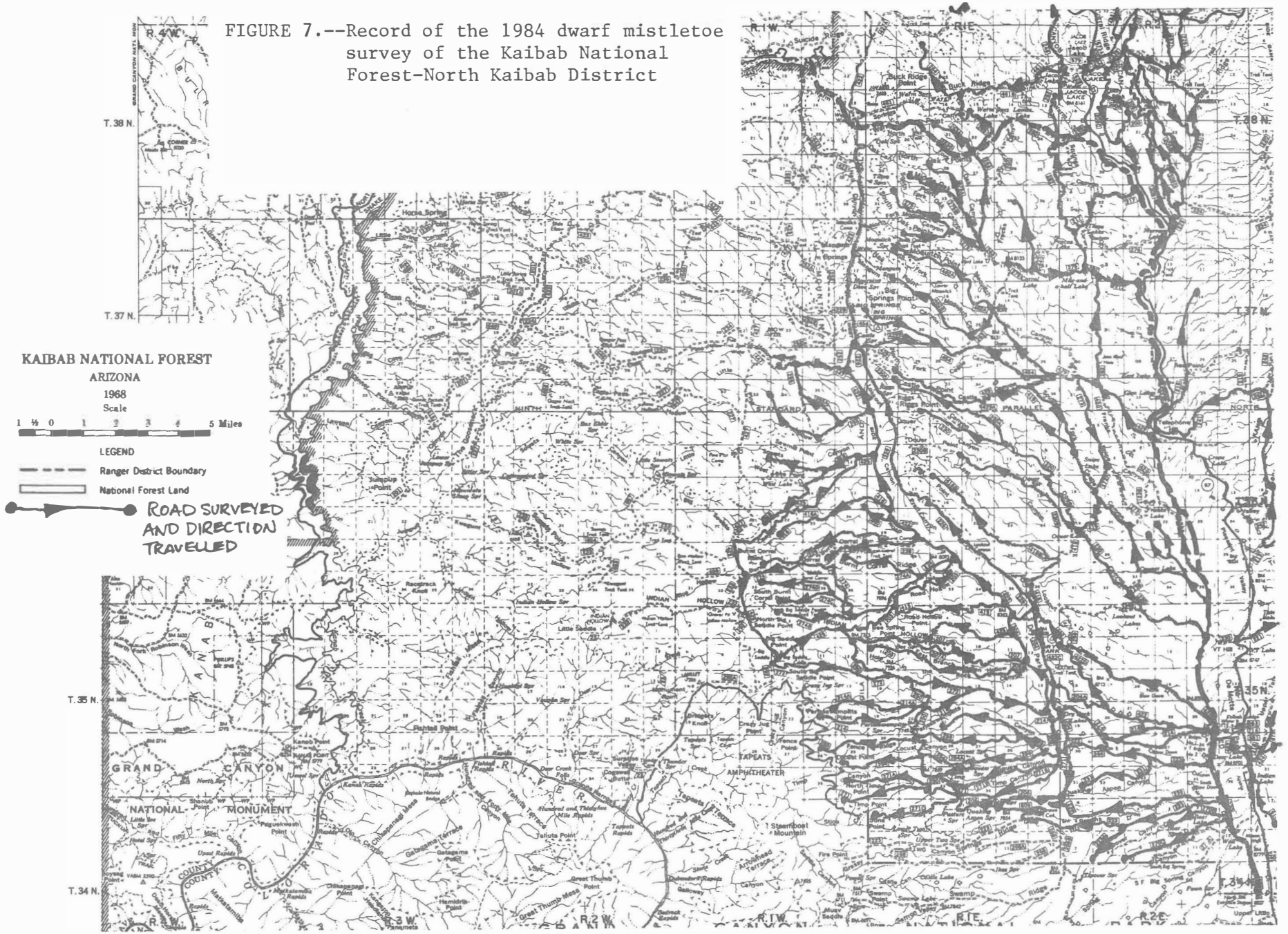
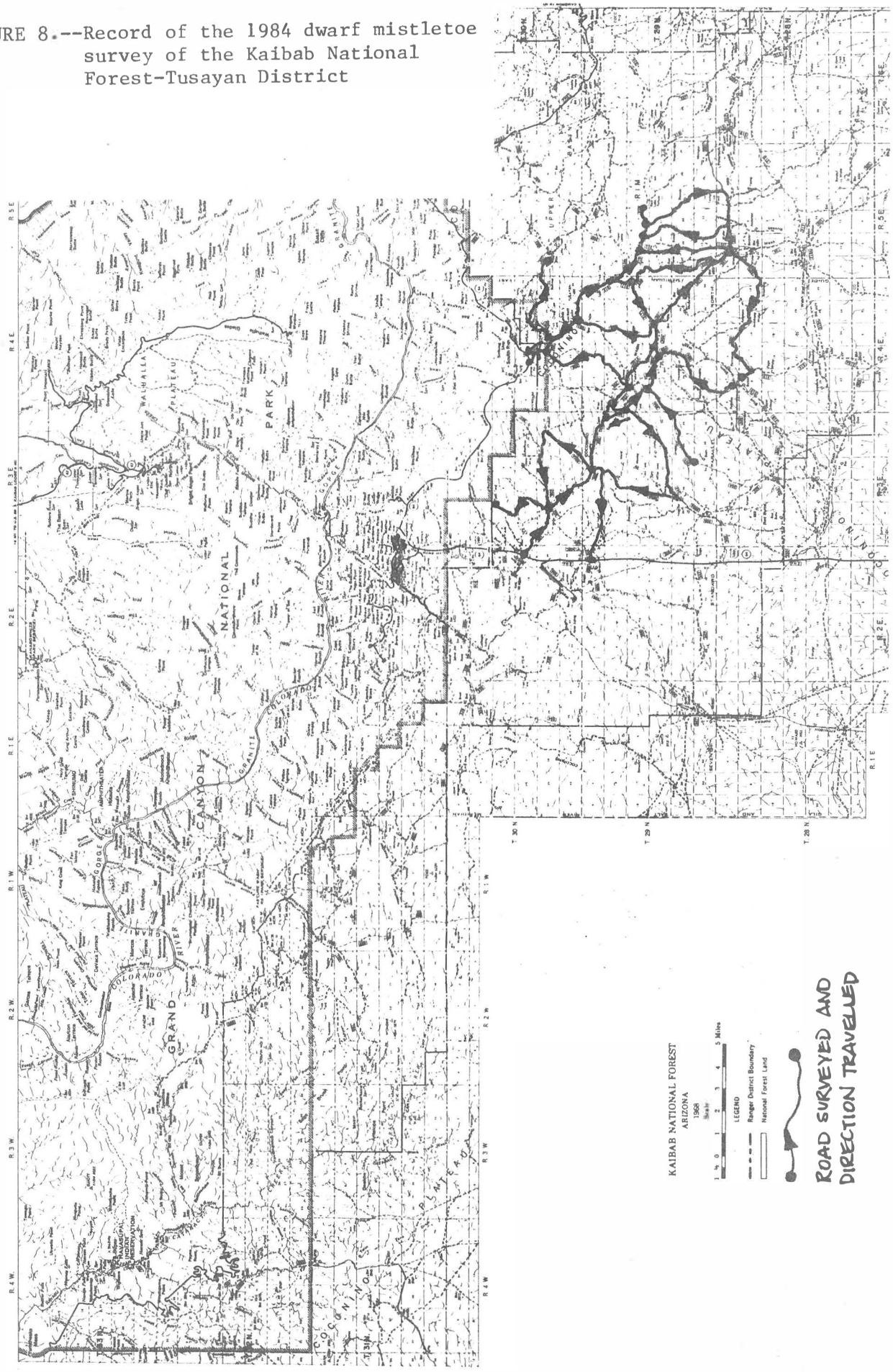

KAIBAB NATIONAL FOREST
ARIZONA
1968
Scale
1 ½ 0 1 2 3 4 5 Miles
LEGEND
Ranger District Boundary
National Forest Land
ROAD SURVEYED AND DIRECTION TRAVELLED
T. 38 N.
T. 37 N.
T. 35 N.
T. 34 N.
R. 4 W.
R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
R. 2 E.
GRAND CANYON NATIONAL MONUMENT
COLORADO RIVER
Hacks Canyon
Saddle Mountain
Big Springs
Jumpup Point
Fishtail Point
Kanab Point
Navajo Point
Shanab Point
Cape Solitude
Point Sublime
Walhalla Glades
Cheops Pyramid
Cheops Mesa
Cheyenne Mesa
Galeyema Terrace
Galeyema Point
Tuna Creek
Tuna Creek Canyon
Jicarilla Point
Tapeats Rapids
Tapeats Amphitheater
Steamboat Mountain
Great Thumb Mesa
Great Thumb Point
Hermits Rest
Hermits Point
Hermit Rapids
Hermit Creek
Hermit Shale Terrace
Dox Creek Falls
Dox Creek
Dox Canyon
Hundred and Thirty-five Mile Rapids
Tuna Creek Rapids
Forty Mile Canyon
Forty Mile Rapids
Mohave Point
Mohave Rapids
Matkatamiba Rapids
Matkatamiba Canyon
Kwagunt Rapids
Kwagunt Canyon
Kwagunt Butte
Kwagunt Hill
Unkar Rapids
Unkar Creek
Unkar Canyon
Nevills Rapids
Nevills Canyon
Buck Ridge
Buck Ridge Point
Jacob Lake
Kaibab Plateau
Kaibab Trail
Kaibab Point
Kaibab Saddle
Kaibab Creek
Kaibab Canyon
Kaibab Rapids
Kaibab Suspension Bridge
Phillips Spring
Robinson Mesa
Robinson Point
Roaring Springs
Roaring Springs Canyon
Roaring Springs Point
Roaring Springs Rapids
Roaring Springs Creek
Roaring Springs Trail
Roaring Springs Trail Tank
Roaring Springs Trail Spring
Roaring Springs Trail Tank
Roaring Springs Trail Spring
Roaring Springs Trail Tank
Roaring Springs Trail Spring

FIGURE 8.--Record of the 1984 dwarf mistletoe survey of the Kaibab National Forest-Tusayan District



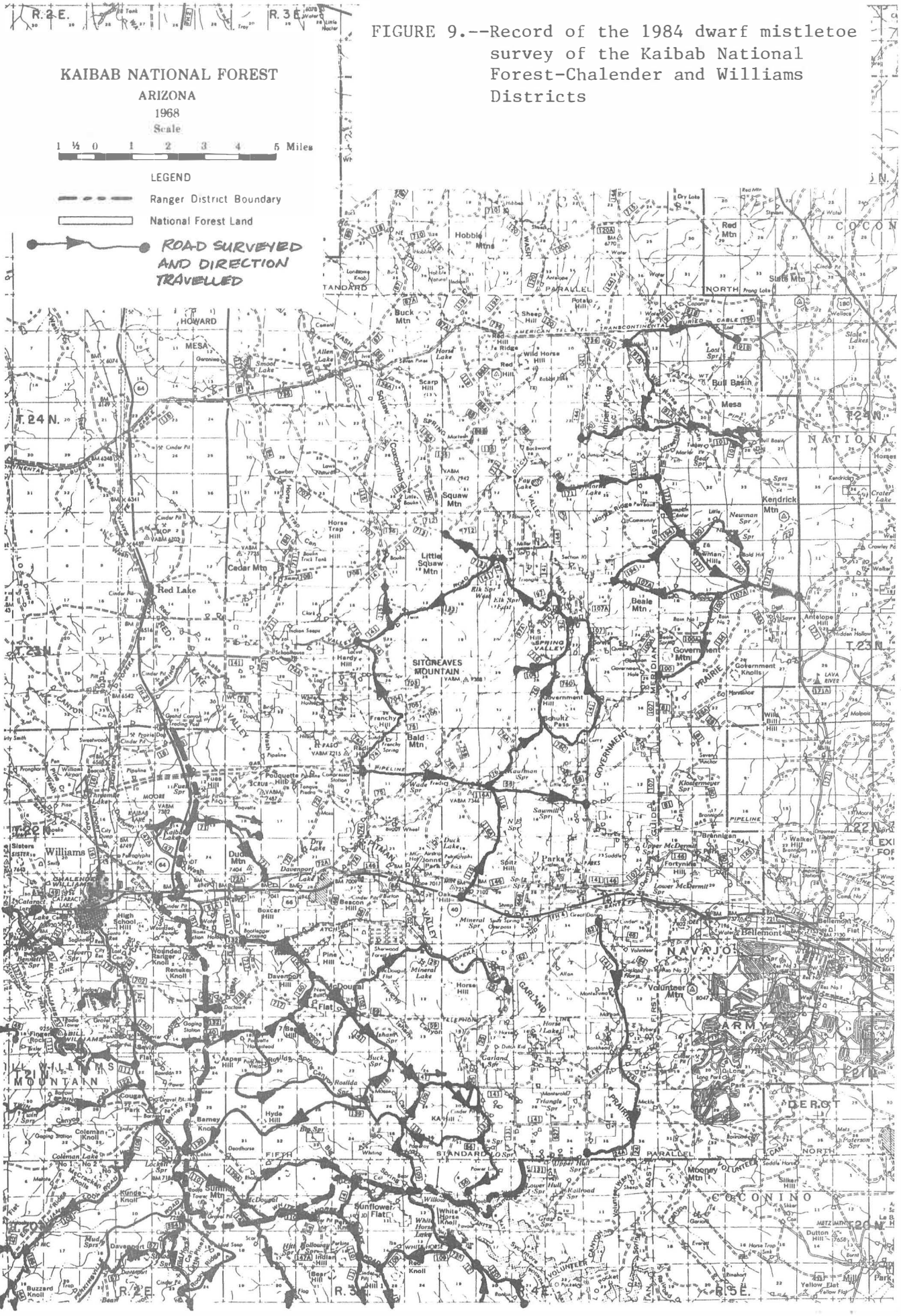


FIGURE 9.--Record of the 1984 dwarf mistletoe survey of the Kaibab National Forest-Chalender and Williams Districts

FIGURE 10.--Record of the 1984 dwarf mistletoe survey of the Kaibab National Forest-Chalender and Williams Districts